FIRRE Command and Control Station (C2)

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ABSTRACT

The Family of Integrated Rapid Response Equipment (FIRRE) is an advanced technology demonstration program intended to develop a family of affordable, scalable, modular, and logistically supportable unmanned systems to meet urgent operational force protection needs and requirements worldwide. The near-term goal is to provide the best available unmanned ground systems to the warfighter in Iraq and Afghanistan. The overarching long-term goal is to develop a fully-integrated, layered force protection system of systems for our forward deployed forces that is networked with the future force C4ISR systems architecture. The intent of the FIRRE program is to reduce manpower requirements, enhance force protection capabilities, and reduce casualties through the use of unmanned systems. FIRRE is sponsored by the Office of the Under Secretary of Defense, Acquisitions, Technology and Logistics (OUSD AT&L), and is managed by the Product Manager, Force Protection Systems (PM-FPS).

The FIRRE Command and Control (C2) Station supports two operators, hosts the Joint Battlespace Command and Control Software for Manned and Unmanned Assets (JBC2S), and will be able to host Mission Planning and Rehearsal (MPR) software. The C2 Station consists of an M1152 HMMWV fitted with an S-788 TYPE I shelter. The C2 Station employs five 24" LCD monitors for display of JBC2S software [1], MPR software, and live video feeds from unmanned systems. An audio distribution system allows each operator to select between various audio sources including: AN/PRC-117F tactical radio (SINCGARS compatible), audio prompts from JBC2S software, audio from unmanned systems, audio from other operators, and audio from external sources such as an intercom in an adjacent Tactical Operations Center (TOC). A power distribution system provides battery backup for momentary outages. The Ethernet network, audio distribution system, and audio/video feeds are available for use outside the C2 Station.

Keywords: command and control, unmanned systems, BAIS, C2, FIRRE, JBC2S, PM-FPS

1. BACKGROUND

The purpose of FIRRE is to provide the best available force protection technologies to our forward deployed forces today, while assisting the Combat Developer in developing concepts and capabilities analysis for the future. FIRRE provides our forward deployed Soldiers, Airmen, Marines and Sailors with an enhanced layered Force Protection System of Systems capability that provides the means to detect, assess, identify and respond to enemy intrusion activities. FIRRE enhances force protection, keeps friendly forces out of harm's way and allows commanders to return Soldiers to their primary wartime missions.

The proponent for FIRRE is the U.S. Army Maneuver Support Center (MANSCEN) at Fort Leonard Wood, Missouri. Current plans call for FIRRE to participate in a July-August 2006 Comprehensive Force Protection (CFPI) Demonstration at Yuma Proving Ground, Arizona and to eventually integrate with the Counter-Rocket, Artillery and Mortar (C-RAM) program as part of MANSCEN's 360 degree Comprehensive Fixed Site Protection concept. If successful this integrated effort will be deployed in FY2007 providing a Force Protection capability against indirect fire and ground intruders.

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The formal requirements for the FIRRE program are being developed by MANSCEN as part of the U.S. Army Training and Doctrine Command's (TRADOC) chartered Unit Protection Concept Capability Plan (UPCCP) Integrated Concept Development Team (ICDT).

The FIRRE Integrated Product Team (IPT) was charted by the OSD Joint Robotics Program (JRP) Coordinator and meets periodically as required. The IPT consists of over 60 members from 10 different agencies. Key members include PM-FPS, SPAWAR, MANSCEN, ATEC, PM-RUS, PM-NV and other members of OSD's JRP.

Over a nine month period, the FIRRE IPT developed an "80% solution" that is affordable, supportable, and uses military equipment where possible or readily available commercial equipment where practical. The resulting system has been demonstrated in two week-long field exercises at Hawthorne Army Depot in Nevada over an operational area in excess of 35 square kilometers. Portions of the FIRRE system have undergone formal environmental testing to include heat (to 120° F), blowing rain (to 40 MPH), shock and vibration, transportability, and center of gravity.

2. SYSTEM OVERVIEW

FIRRE has been designed to be deployed in a rapid fashion for tactical missions, or integrated into base operations as part of a complete force protection package. As FIRRE is a system of systems, its configuration is flexible and scalable, and the exact table of equipment for a particular application is based upon METT-T (Mission, Enemy, Troops, Terrain, and Time). Nominal deployment of FIRRE consists of a single C2 Station controlling multiple unmanned assets operating over an area of approximately 100 square kilometers that approaches the physical extents of the current communications architecture. A typical FIRRE system for performing perimeter security of a moderate-sized (7 x 5 kilometer) ammunition base could consists of:

- 1 M1152 HMMWV
- 1 S-788 TYPE I Shelter housing C2 Station Equipment
- 6 Blue Sky Masts with Radio Antennas
- 1 PU798 10KW Generator Trailer
- 2 M1102 Support Equipment Trailers
- 4 Remote Sensor Stations
- 50 BAIS Unattended Ground Sensors
- 2 FIRRE Unmanned Ground Vehicles

2.1 C2 Station (M1152 HMMWV with S-788 TYPE I shelter)

The C2 Station is a self-sustaining mobile command post for operating multiple remote unmanned assets (sensors, vehicles, systems). The C2 Station is housed in an *S-788 TYPE I* shelter that rides on an *M1152 HMMWV* (Figure 1). The *M1113 HMMWV* is an acceptable substitute for the *M1152 HMMWV* in terms of its weight carrying capacity.

The interior of the C2 Station consists of an operator console with seating for two users, a power distribution rack, a computer systems rack, and a communication systems rack. Space for a third user is provided by a jump seat located on the rear door. Wall mounts for two M-16 rifles are provided for convenient storage of weapons. A safe is available for storage of COMSEC materials (KEYMAT).

2.1.1 Operator console

The operator console is a fixed desktop workspace that supports two operator stations. Each operator station has: keyboard, trackball, joystick, headphones, microphone, audio mixer, computer monitors, and adjustable chair (Figure 2).

Figure 1: C2 Station (M1152 HMMWV with S-788 TYPE I shelter).

Figure 2: Operator console.

User input/output devices are connected to an *Avocent KVM* multi-port switch so that each operator station has instant access to any of the computing resources in the C2 Station. Simple keyboard commands allow the operator to switch

keyboard, trackball, and the secondary (bottom) monitor of the workstation between any of five computer systems. This provides a redundant capability in case of an equipment failure, allowing the operator to activate a back-up computer without leaving his/her seat.

Five *Dell 2405* 24-inch digital LCD monitors are used to display application software and live video feeds from the unmanned systems. The *Dell 2405* monitor has multiple video inputs, can display multiple video streams simultaneously using picture-in-picture, and is capable of image resolutions up to 1920 x 1200 pixels. The monitors also have an integrated Universal Serial Bus (USB) interface and a 9-in-1 Flash card reader provided on the side of the display case; the USB interface supports standard devices such as external keyboards, mice, cameras, etc. Two monitors are located in front of each operator station, while the fifth (center) monitor is located between the two stations (Figure 2). The two operator station monitors, are dedicated as computer screens for FIRRE application software. The center monitor is used to display real-time video from the unmanned systems. An *RGB Spectrum* eight-port video multiplexer tiles incoming imagery for display on the center monitor; the multiplexer has two banks of four channels and can display four images simultaneously in several pre-defined window sizes/positions. The multiplexer can automatically sequence through all eight video channels, displaying each channel in full resolution for a predefined time period. The center monitor (on its secondary input) is also capable of displaying multiple digitized video signals that are routed through the dedicated network video recorder computer.

A *Riedel Artist RCP-1012* digital intercom system is used to allow each operator to select between various audio sources. Audio sources include: *AN/PRC-117F* tactical radio (SINCGARS compatible for access to a Quick Reaction Force and higher headquarters), digitized audio prompts from JBC2S software, audio from unmanned systems, audio from the operator stations, and audio from external sources such as an intercom in an adjacent Tactical Operations Center (TOC). The *Riedel Control Panel* allows the operator to set the sound level of each incoming audio source separately and to mix all audio sources together into a single stream, allowing all of the audio sources to be monitored simultaneously. *Riedel M2* double-ear noise-canceling headsets with boom microphones are used with the intercom system, which allows operators to communicate with all FIRRE manned and unmanned assets from the C2 Station through the push of a button. A separate audio switch and audio amplifier route sound from the C2 Station computers and from the digital intercom system to stereo speakers that are mounted inside the shelter for distribution to all C2 Station occupants.

A *Daco MG1* 2-axis high-precision joystick, *Daco DT620* ergonomic trackball, and *Input Technologies* industrial 85-key keyboard are embedded in the workstation desktop, and are the primary computer I/O devices used to operate the FIRRE system. The joystick is used to teleoperate the FIRRE Unmanned Ground Vehicle (UGV), as well as aim steerable sensor subsystems such as cameras and radars.

Controls for the Environmental Control Unit (ECU) such as FAN ON/OFF, THERMOSTAT, and HEAT/COOL ON/OFF are positioned above the console for easy access by operators. The ECU is a 36,000 BTU device from *Applied Companies*, and is located on the exterior of the C2 Station upon a heavy-duty rack mounted to the *S-788 TYPE I* shelter. The ECU is capable of maintaining a temperature of approximately 85° F within the C2 Station, with an ambient temperature of 120° F.

Figure 3: Power distribution *(right),* computer systems racks *(left)*.

2.1.2 Power distribution rack

The power distribution rack (Figure 3) holds the Power Distribution Unit (PDU) and a series of Universal Power Supplies (UPS).

The PDU converts and conditions electricity for use inside the C2 Station. Three-phase, 208 VAC, 60 Hz, 40 AMP power is supplied to the C2 Station from either a shore or generator source. The three-phase power is fed directly to the ECU, and is also converted to 120 VAC which is then fed to three *Liebert GTX2* 2 KVA UPS. The UPS are wired to a series of circuit breakers within the PDU; the PDU then distributes power to electrical

equipment within the C2 Station. The UPS can supply 20-30 minutes of run time when a power failure occurs, which basically allows the operators to gracefully shut down the system while power is being restored.

A smart power metering system is provided on the PDU. It monitors and displays voltage, current, and phase readings for all three lines of the power supply, as well as overall system voltage, current, and phase for the 120 VAC side of the PDU. The power-up sequence of the C2 Station takes as little as 15 minutes; that is, from the time that the C2 Station is parked and the radio antennas are erected, the C2 Station can be fully operational in 15 minutes.

2.1.3 Computer systems rack

The computer systems rack (Figure 3) holds the digital intercom system controller, the black network Ethernet switch, the video distribution system amplifiers, the multi-port computer interface switch, the industrial computer systems, and the Network Attached Storage (NAS) device.

The *Artist RCP-1012 Riedel* digital intercom system main controller is housed in the computer systems rack, and is connected to the two operator station control panels. The intercom system digitizes all of the incoming and outgoing audio sources and then distributes the digitized audio across an audio network that operates much like an Ethernet network. The intercom system can be expanded by connecting additional control panels to the audio network using standard Ethernet (CAT 5) cable. This allows additional users located outside the C2 Station to communicate across the audio network.

Figure: 4. JBC2S software.

The output signal from the video card of each industrial computer system is run through a VGA video distribution amplifier that splits the video signal for transmission to the operator console monitors (via the *Avocent KVM* switch) and to the left-rear egress panel on the outside of the C2 Station, for viewing on an external monitor located in an adjacent TOC.

The keyboard, mouse, and video interface for each industrial computer system are fed through the *Avocent KVM* multi-port switch so that operators can access any of the computers from their seats; special keyboard commands activate a menu system on the *KVM* that allows the user to switch between computers and to configure the *KVM* interface.

The C2 Station employs two separate Gigabit Ethernet networks; a black network is used to transmit unclassified data and a red network is used to transmit classified data. A *Cisco 3560 24-port 10/100/1000 Base-T* Ethernet switch serves the black network, and is connected to the industrial computer systems, the NAS, the serial-to-Ethernet switch, and the digital audio/video CODECs. A *Cisco 2811 Secure Router* serves the red network, and is connected only to the secondary network card in each of the industrial computers. The *2811 Secure Router* provides IPSEC and has built-in AES 256 encryption. The red network is intended to be used to process and share classified data such as that provided by Blue Force Tracker, FBCB2, or GCCS. The red network router is physically located in the communications systems rack, as far away from the black network switch as possible.

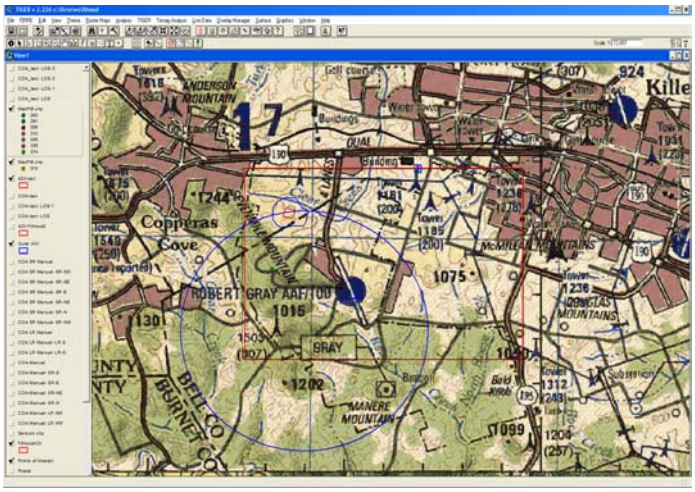

Figure 5: MPR software.

Five Pentium-class industrial computers are used to host the FIRRE software, consisting of: Joint Battlespace Command and Control System for Manned and Unmanned Assets (JBC2S), which is the application software developed by SPAWAR Systems Center, San Diego that provides control for and situational awareness of all FIRRE unmanned systems (Figure 4); Mission Planning and Rehearsal (MPR) software used by commanding officers to configure the mix and placement of sensors to provide coverage for a particular facility (Figure 5); and additional application software, including *ESRI ArcGlobe* terrain visualization software (Figure 6) and *IndigoVision Command Center* network video recording software (Figure 7). *Windows XP Professional* is the computer operating system. Two backup computers provide redundancy in case of a failure. Each computer system has: 3.6 GHz Pentium 4 CPU, redundant power supplies, removable 74 GB serial ATA disk dive, re-writable DVD drive, dual *ATI FireGL* graphics cards, dual 1 Gbps Ethernet network cards, and 1 GB RAM. The two network cards provide isolation between the black and the red Ethernet networks, which are physically separate, except within the computer system chassis where they are electrically connected across the motherboard bus.

An *Excel Meridian DataNAS XP* provides 500 GB of computer data storage space that is accessible across the network by all computer systems. The NAS has hot-swappable power supplies, 512 MB cache memory, a re-writable DVD drive, and supports up to eight RAID level 5 disk drives providing a current maximum capacity of one Terabyte of data storage, which can be easily increased by using higher-capacity disk drives. The DVD drive can be used to copy important mission data to removable media for distribution to higher headquarters and for archival purposes. The NAS acts as a centralized file server – computer systems map the NAS as logical disk drives under *Windows XP*. The NAS will typically store high-resolution map data, digitally recorded audio and video, shared FIRRE application software data, technical manuals, and training material.

2.1.4 Communications systems rack

The communications systems rack holds the unmanned systems data radios, the unmanned systems audio/video receivers, the red network Ethernet router, the multi-port serial-to-Ethernet server, the audio/video CODECs, the base station GPS receiver, dual BAIS receivers, and dual *AN/PRC-117F* tactical radios. A media storage shelf holds system documentation and backup copies of all system software on CD (Figure 8).

The communications scheme currently being used for FIRRE includes point-to-point radio links using commercial equipment. This is an economical approach that provides an expandable near-term solution (more than 80%). A full-up military solution is extremely expensive, and involves equipment with lead times of up to a year. Candidate military radios for possible future use (e.g., follow-on acquisition phase) include the *AN/VRC-99*, the *EPLRS*, and of course the *JTRS* when available.

The current FIRRE solution provides for control of up to six unmanned systems (fixed or mobile) simultaneously. In FY05, funds were available to procure and integrate radio equipment to control three unmanned systems, which were sufficient to support testing in January/February 2006. In FY06, funds will be allocated to procure and integrate the remaining three radio systems that provide support for control of, for example, three FIRRE UGVs and three Remote Sensor Stations, including multiple BAIS sensors, at the same time. This will meet FIRRE near-term requirements. Support for control of additional unmanned systems will require

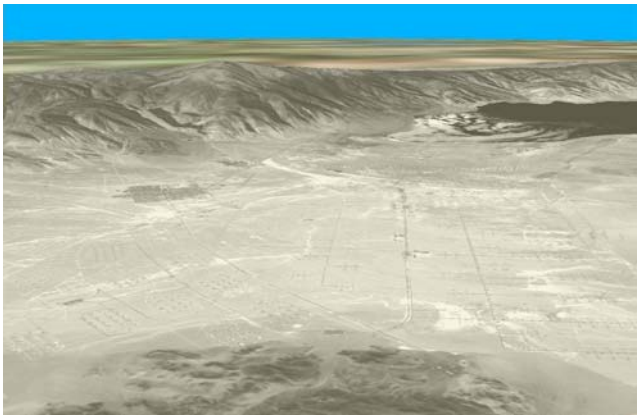

Figure 6: ESRI ArcGlobe software.

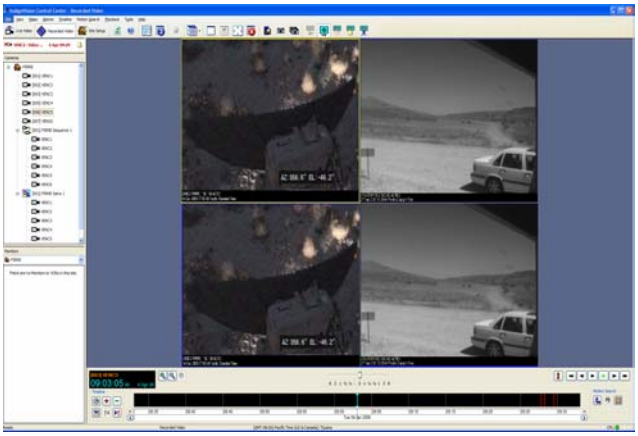

Figure 7: IndigoVision Control Center software.

migration of equipment out of the C2 Station through the rear egress panels and into a fixed TOC – the equipment racks in the current C2 Station are full.

Figure 8: Communications systems rack.

Three radio systems are being employed: *Intuicom Military Navigator II* radio for bi-directional C2 data; *DTC Palladium* COFDM[1] radio for audio/video downlink from unmanned systems; *Harris AN/PRC-117F* tactical radio for coordination with Quick Reaction Force (QRF). One *AN/PRC-117F* is fixed in the C2 Station communications systems rack, and a second amplified *AN/PRC-117F* is mounted in the cab of the HMMWV for communications while in transit (this radio will be moved into the C2 Station communications systems rack when the unit is in position so that both operators have a dedicated QRF radio link). The *L3 Communications AN/PRS-9 (BAIS)* receiver and the *Novatel ProPak-G2 (RT2)* GPS receiver are also being used.

The *Intuicom Military Navigator II (MilNavII)* radio has a serial interface with an aggregate bandwidth of 115 Kbps. Three separate ports (physical interfaces labeled A, B, and C) are provided on the unit with the ability to treat each port as a separate data channel. The A port is used as the C2 data channel, the B port is used to distribute differential GPS correction data to all unmanned assets, and the C port is used either as a debug port or as a digital audio uplink (to transmit digitized audio to the unmanned assets). The *MilNavII* radio supports both direct-frequency operation and frequency-hopping. The radio operates over the 225 MHz – 400 MHz frequency range and uses approximately 230 KHz channel bandwidth. It is able to operate in a repeater mode to extend effective range, and is capable of synchronizing transmissions to facilitate operating multiple radio systems simultaneously in close proximity.

The *DTC Palladium* COFDM transmitter is used to send audio and video from unmanned assets to the C2 Station. The radio operates in the 1.700 to 1.855 GHz frequency range[2] and uses 2.5 MHz channel bandwidth. Video quality is exceptional with very low-latency (< 45 ms average). Transmissions can be encrypted using AES 256. The *Palladium* receivers are mounted in the communications systems rack, and video from each receiver is routed to an analog video amplifier that is then fed to both the *RGB Spectrum* eight-port video multiplexer for display on the center video monitor and to an *IndigoVision VB8000* digital audio/video CODEC. This allows the low-latency video to be viewed directly by the operator and to be recorded digitally at the same time.

The *VB8000* is MPEG-4 hardware CODEC that digitizes the incoming audio/video stream and then serves the digitized stream over the Ethernet network. Multiple digital audio/video streams can be served and viewed simultaneously to users anywhere on the network. The MPEG-4 CODEC can be configured to optimize bit-rate, frame-rate, and image quality, and can be programmed to detect motion in the visual scene. Alarms can be generated from detected motion. The *VB8000's* are typically configured to stream data to the *IndigoVision Control Center* application program that runs on one of the industrial computers. The *Control Center* is a COTS product that is intended to manage networks of digital video cameras in security applications. It supports viewing multiple video streams simultaneously in a tiled fashion, provides alarms based upon video motion detection, and supports recording and playing back digital audio/video streams. This approach provides the ability to record audio/video from all of the unmanned assets simultaneously for post-event processing and analysis; the streaming data is recorded digitally on the network video recorder, which has access to over 500 GB of disk storage.

[1] Coded Orthogonal Frequency Division Multiplexing – COFDM – is a modulation scheme that is resistant to multipath effects because it uses multiple carriers (sent at right angles to each other) to transmit the same signal.
[2] The DTC Palladium radio is offered at various frequencies ranging from 300 MHz to 6 GHz.

A *Comtrol Device Master RTS* 16-port serial-to-Ethernet server connects nearly all of the serial devices within the C2 Station to the Ethernet network. This allows the serial devices to be accessed as IP devices over the network. This means that all of the serial devices within the C2 Station are also accessible outside the C2 Station as the network is run outside the C2 Station via the shelter egress panels. A *Windows XP* device driver is installed on the industrial computer systems that enable application software to access the serial devices using either TCP/IP sockets or extended range communications (COM) ports. This allows JBC2S to interface to a device, such as an unmanned ground vehicle as either a serial entity or an IP entity. The current *Comtrol* 16-port server is full, and plans are to expand to either a 32-port unit or to add a second 16-port unit. This is necessary as efforts are underway to add all of the three serial ports (A, B, C) on the *Intuicom* radios to the *Comtrol* server.

The *Novatel ProPak-G2 (RT2)* GPS receiver is used as the base station for the FIRRE system. The *ProPak-G2* is a differential, real-time-kinematics (RTK), dual-band (L1/L2), 12-channel GPS receiver. It is used primarily to provide the location of the C2 Station to JBC2S, and as a source for differential GPS correction data for the unmanned systems. The GPS receiver is programmed to periodically output a sequence of differential GPS correction reports that are routed to an RS-232 serial data splitter that is then connected to the B port on the *MilNavII* data radios. This provides a "broadcast" differential GPS correction to all unmanned systems so that they can more accurately report their position. A diagnostic program is provided with the *ProPak-G2* that allows a maintainer to display the positions of the GPS satellites, verify the position of the GPS base station, verify proper operation of the receiver, and configure the receiver to output correction reports.

Two *L3 Communications AN/PRS-9 Battlefield Anti-Intrusion System (BAIS)* handheld monitors are mounted in the communications systems rack, and provide a local (redundant) capability to receive BAIS sensor reports. The serial output from the BAIS handheld monitors is routed to the serial-to-Ethernet server so that the sensor data is available across the Ethernet network. The alarms from the BAIS handheld monitors are also audible (barely) and visible within the C2 Station, so that FIRRE operators know when a BAIS sensor (Figure 14) has triggered. This is a redundant capability in that the typical FIRRE operational scenario places the BAIS sensors perhaps over 10 KM from the C2 Station, and assumes the use of the Remote Sensor Station (RSS) to receive BAIS sensor reports and forward them over the C2 data link to JBC2S for integration into the situational awareness displays. The BAIS handheld monitors in the C2 Station provide an organic capability that could be used in cases where the RSS is not available or not desired, which may be the case in a tactical situation where the C2 Station is quickly driven into position perhaps specifically to listen to BAIS sensor reports.

Two *Harris AN/PRC-117F* tactical radios are mounted in the communications systems rack, and provide connectivity to the military network. The *PRC-117F* is SINGARS compatible and can operate in secure (COMSEC) voice and data modes. It is an extremely versatile multiband radio that covers the entire 30 to 512 MHz frequency range using two antenna ports for optimum range performance. An external SATCOM antenna can be connected to the *PRC-117F* for world-wide connectivity and coordination of FIRRE missions. Each operator has a dedicated tactical radio for outside communications. It is intended that the QRF will be dispatched via the *PRC-117F* from the C2 Station in response to threats assessed using FIRRE unmanned assets.

Figure 9: C2 Station egress panels.

2.1.5 Egress panel

Three egress panels are installed at the rear of the shelter. The egress panels support the external connections to the C2 Station. The panels are replaceable and can be configured to meet mission requirements. One egress panel supports power, a second panel supports external data communications interfaces, and a third panel supports all of the external antenna connections. All of the video feeds, the Ethernet network, the digital intercom system, and the external audio speakers

are routed to an egress panel at the rear of the shelter and are available for use outside the C2 Station. Since the network is available outside the C2 Station, nearly all functions available inside the C2 Station can be accessed externally. The C2 Station is highly expandable via the egress panels that can be re-configured to support a variety of physical interconnections (Figure 9). Standard *S-788 TYPE I* shelter boots are available that allow the C2 Station to be connected to stock military tent systems such as the BASE-X tent. This provides a standard mechanism for integrating the C2 Station with existing (tent-based) operations centers.

2.2 Communications – Blue Sky Masts with radio antennas

The C2 Station shelter includes external mounts for up to six (6) antennas. The antenna mounts are modular in that they can support any one of the different types of radio antennas employed under FIRRE. Using the six mounts, a minimum quick-response FIRRE configuration can be deployed that uses:

- 1 GPS base station antenna (mounted on the front of the shelter, not using a modular mount position)
- 2 AN/PRC-117F (QRF) antennas (modular mount position #1)[3]
- 2 AN/PRS-9 antennas (modular mount positions #2, #3)
- 1 Intuicom C2 data antenna (modular mount position #4)
- 2 DTC audio/video antennas (modular mount position #5, #6)

This configuration, which can be setup in a matter of minutes, will support operation of two tactical QRF radios, two BAIS receivers for operation of over 120 BAIS sensors, and one unmanned system (e.g., UGV or RSS tower). The antennas attached to the modular mounts can be configured in a myriad of ways that could provide support for a number of FIRRE missions without the need for emplacing ground-based, guyed antenna masts.

In order to fully employ the C2 Station, external heavy-duty tripod masts – guyed to the ground – are used to support the radio antennas. The *Blue Sky* 10-meter modular mast system is used to mount and erect the FIRRE radio antennas. Three antennas per unmanned system (that can be placed on the same antenna pole erected on a single mast), plus up to two *AN/PRS-9* handheld monitor antennas, one GPS receiver antenna, and two *AN/PRC-117F* antennas are required to support operations. For example, the C2 Station will require up to 23 antennas on 10 separate masts to support six (6) unmanned systems. Efforts will be made to optimize the final antenna configuration to reduce the part count and facilitate installation.

Technical issues relating to EMI and/or frequency authorization/assignment may affect the final system configuration – FIRRE may be forced to limit operation in terms of the number of devices that can be controlled simultaneously. The radio solution is currently being tested, and efforts are underway to aggressively pursue frequency authorization/assignment with the Joint Spectrum Center (JSC).

2.3 PU798 10KW generator trailer

The *MEP PU798* 10KW diesel generator supplies power to the C2 Station (Figure 10). It is a type classified Tactical Quiet Generator (TQG) from Product Manager, Mobile Electric Power (PM-MEP). It is pulled by the C2 Station while moving into position. Standard operating procedure indicates the use of a second unit in order to "hot swap" with the first unit as it is being re-fueled and serviced. (Full battery backup of the entire C2 Station electrical system could be supported in the future, but it may be more cost effective to simply have a secondary/backup generator.) The *MEP PU798* supplies power to the C2 Station for as long as 12 hours before requiring refueling, depending upon the use and duty cycle of the ECU.

2.4 M1102 support equipment trailer

The *M1102* support equipment trailer will be towed by a second HMMWV that will need to be made available by the deploying unit when in theatre (Figure 11). The trailer currently being used by FIRRE has an extended bed (120" vice 86"); the base trailer is type classified. The trailer and the HMMWV are used to haul the FIRRE support equipment. The support equipment includes: RSS towers, Ground Surveillance Radars (GSR), Unattended Ground Sensors (UGS), visual sensors, portable generators, electronics boxes, antenna masts, antennas, cables, and camouflage netting. The trailer and

[3] The second AN/PRC-117F antenna would be mounted on the front of the shelter and would not use a modular mount position. This is the normal location for this antenna when the C2 Station is in transit.

HMMWV are capable of loading two complete RSSs at a time. The FIRRE UGVs will have to be transported separately with a heavy duty tractor trailer, and off-loaded with a crane or heavy duty fork truck.

Figure 10: PU798 10KW generator trailer.

Figure 11: M1102 support equipment trailer.

2.5 Remote Sensor Station (RSS)

The RSS (Figure 12) supports the Ground Surveillance Radar (GSR), the Unattended Ground Sensors (UGS), and the thermal imaging system/visual imaging system (TIS/VIS) sensor, and will be deployed at the perimeter to provide remote sensing to the extents of the equipment's capabilities [2]. The RSS consists of: 20 foot collapsible tower, guy wire kit, 531A 2KW portable generator (type classified), *AN/PPS-5D* GSR, *DI-5000* TIS/VIS, C2 data radio antenna, audio/video downlink radio antenna, GPS antenna, *AN/PRS-9* antenna, electronics box, camouflage netting, and interconnect cables.

Figure 12: Remote Sensor Station (RSS).

An *MEP 531A* diesel generator supplies power to the RSS electronics box and can support 24+ hour operation with one five-gallon can of diesel. Two five gallon cans will be plumbed into the generator through a simple flow-valve such that the user simply has to turn the knob on the valve to switch between fuel cans.

The RSS electronics box is a thermoelectrically cooled transit case that houses the sensor control and interface equipment. It is insulated to maintain a safe operating temperature in extreme conditions (< 120 degrees F). The enclosure contains: thermoelectric cooler, temperature sensors, power conditioning unit, DC power supply, *AN/PRS-9* receiver, C2 data radio, audio/video downlink radio, and embedded computer.

The GSR, UGS, and TIS/VIS are interfaced to the embedded computer in the RSS electronics box. The data from the sensors is processed and sent back to the C2 Station, where it is displayed within JBC2S. Remote controls are provided through JBC2S for each sensor. Sensor data processing will increase in complexity over time as the system is tested; the utility of the system will increase as the sophistication of the data processing improves (crawl first, walk later). The user will decide what is useful and FIRRE will adapt as possible (limited only by available resources).

2.6 BAIS sensor

Each RSS includes an *AN/PRS-9* handheld monitor. BAIS sensor fields will be placed around the perimeter as dictated by MPR software. The individual BAIS sensors (seismic/acoustic) communicate to a BAIS receiver that is located within the electronics box of an RSS (nearest the sensor field). The BAIS sensors report to an RSS, the RSS then passes the data to the C2 Station where it is displayed using JBC2S. The BAIS sensor data can be sent much longer distances using this approach. As FIRRE currently owns 30 BAIS sensors, nominally there will be 10 sensors associated with each RSS; ultimately, this is dependent upon the MPR software. The BAIS sensors will be used to queue the dispatch of the FIRRE UGV to an area of alarm; when the BAIS sensors alarm, the system will query the operator and ask for permission to send a FIRRE UGV to a predefined point that is close to the location of the alarm (nearest the BAIS sensor field where the alarm occurred) (Figure 13).

Figure 13: BAIS sensor.

Figure 14: FIRRE UGV.

2.7 Unmanned ground vehicle (UGV)

The UGV will provide unmanned mobile detection and assessment capabilities, and will operate in a semi-autonomous mode. The candidate FIRRE UGV (Figure 14) is a highly-mobile tracked vehicle that will include: multiple driving cameras, the *AN/PPS-5D* GSR, the FLIR Systems *SeaFLIR*, lights for night time operation, audio speakers for local sound projection, microphones for local sound reception, sensors for vehicle condition, sensors for navigation, sensors for obstacle detection, embedded vehicle control computer, embedded navigation behavior computer, C2 data radio and antenna, audio/video downlink radio and antenna, GPS antennas, and a power generation/conditioning/distribution system. Under normal operating conditions, the UGV will be automatically dispatched according to a schedule established by the company commander. The UGV will be put on patrol, sent to pre-programmed points of interest, and commanded to perform security detection scans of areas of interest. A variety of actions can be performed along paths as the UGV moves between points of interest. If the UGV senses an obstacle in its path while in motion or stationary, it will stop and request assistance from the operator before proceeding. The UGV will not attempt to go around an obstacle on its own. The operator will have to manually drive the UGV around the obstacle, and then resume the UGV on its path. This behavior is commensurate with the level of vehicle autonomy that was achievable during the early phase of the FIRRE program.

3. FUTURE PLANS

Planned C2 Station modifications include 1) replacement of individual *IndigoVision VB8000s* with the 10-channel rack-mount device; 2) re-ducting of the ECU to provide better air circulation toward the rear of the shelter; 3) addition of a break-out box for the GPS correction data splitter to the *MilNavII* radios; and 4) expansion of the 16-port serial-to-Ethernet server to a 32-port unit.

Future plans for FIRRE include integration with the Counter Rocket, Artillery and Mortar (C-RAM) program as the ground component in an overall force protection system for forward operating bases. FIRRE will be integrated with C-RAM as a remotely deployed sensor system, and will communicate with the C-RAM C2 system using the enhanced Tactical Automated Security System (eTASS) protocol. JBC2S will be extended to use eTASS as a C2 module, and will

serve data to C-RAM and accept data queries from C-RAM. A *Redline Communications AN-50e* radio will be added to the communications systems rack, and antenna connections will be added to the shelter egress panel. The *AN-50e* operates in the 5.4 – 5.8 GHz frequency range, occupies 20 MHz of channel bandwidth, and has an average throughput of approximately 49 Mbps over the Ethernet interface. The radios have been used in the past on FIRRE and were found to be very reliable and easy to use.

Additional plans include integration of FIRRE with a multitude of other unmanned systems including Unmanned Surface Vehicles (USVs), Unmanned Aerial Vehicles (UAVs), and other Unattended Ground Sensors (UGSs). SPAWAR Systems Center, San Diego has already demonstrated the simultaneous C2 of a UGV, a USV, and a UAV using the Multi-Robot Operator Control Unit (MOCU), which is the foundation for JBC2S) [3]. FIRRE will push the readiness level of the unmanned systems and integrate the platform control into JBC2S.

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